1914
Anl

ANDERLE

The Effect of Temperature on the Electrical Resistance of TiO_2, Mg O, and $AL_2 O_3$

Ceramics

B. S.

1914

UNIV. OF
ILLINOIS
LIBRARY

THE UNIVERSITY
OF ILLINOIS
LIBRARY
1914
An1

THE EFFECT OF TEMPERATURE ON THE ELECTRICAL RESISTANCE OF TiO_2, MgO, AND AL_2O_3

BY

EMIL J. ANDERLE

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CERAMICS

COLLEGE OF LIBERAL ARTS AND SCIENCES

UNIVERSITY OF ILLINOIS

1914

1914
Am1

UNIVERSITY OF ILLINOIS

June 1st 1914

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Emil J. Tinderle

ENTITLED The Effect of Temperature on

The Electrical Resistance of TiO_2, MgO and Al_2O_3

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

in Ceramics

R J Stull

Instructor in Charge

APPROVED: R J Stull

HEAD OF DEPARTMENT OF Ceramics

917.32

UIUC

-TABLE OF CONTENTS-

		Page
I.	Introduction	1
II.	Apparatus	5
III.	Method	6
IV.	Results	6
V.	Conclusion	8
VI.	Data	9
VII.	Curves	23

Digitized by the Internet Archive
in 2013

http://archive.org/details/effectoftemperat00ande

The Effect of Temperature on the Electrical Resistance of TiO_2, MgO, and Al_2O_3

-INTRODUCTION-

In many branches of scientific work, high temperatures are often required. For this purpose we have at present several methods of acquiring these temperatures, but each of these has disadvantages which at times causes these methods to become unsuited for certain definite purposes. The platinum-resistance furnace can be used with excellent results to a temperature of 1500°C., but it is disastrous to run it higher, for at this point the platinum begins to melt, since the temperature of the platinum conductor is much higher than the temperature of the furnace chamber. Also, volatilization of the platinum causes rapid deterioration. Sir William Crookes[1] found that volatilization takes place as low as 1300°C., but the loss at this point is not very great.

The De Ville furnace, (fig. 1) which burns charcoal or coke under forced draft cannot be used for accurate work as the temperature cannot be regulated at will.

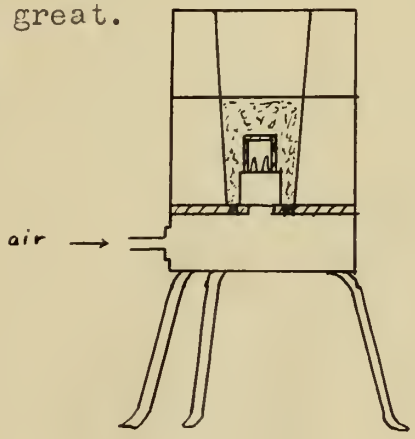


Fig 1.

The best furnace we have at present for temperatures above 1500° is the carbon-resistance furnace, (fig. 2) but it has two serious disadvantages. The first of these is that the carbon gradually

.....

[1] Transactions 'Royal Society of London'
Vol. 86 Series A pp. 472
'Volatilization of the metals in the Platinum Group'.

wastes away by oxidation if used in the atmosphere, making it necessary to renew the carbon frequently. The second disadvantage probably affects the ceramic chemist most, for in his work it is often necessary that he have oxidizing conditions, and in a furnace of the carbon-resistance type carbon monoxide is always present in the chamber when operated under atmospheric conditions

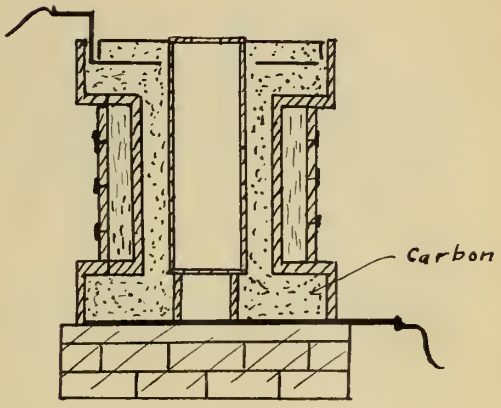


Fig 2

For temperatures up to 2000° we have the iridium furnace[2] measuring the temperature with an optical pyrometer (fig. 3). It consists of an iridium tube about 20 mm. in diameter, which conducts a current. This tube is surrounded by magnesia and an outer tube of asbestos. This type of furnace is not very practical for severe service because of its initial cost and high cost of upkeep, and the amount of current required.

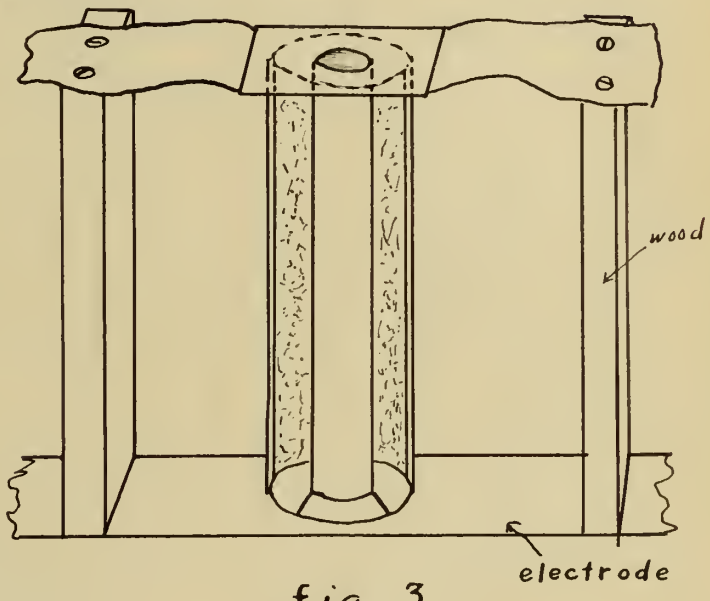


fig. 3

.....

[2] 'Der Elektrische Offen' by J. Bronn. pp. 73.

A furnace which can be used for temperatures up to 3000° is the tungsten-resistance furnace.[3] (Fig. 4) It consists of a small tube of tungsten held between the ends of two electrodes connected with a transformer for a heavy current. The material to be heated is placed in a magnesia boat in this tube. Platinum, iron, iridium, etc. may be substituted for the tungsten. The heating element is surrounded by an evacuated, water-cooled, glass bulb. This type of furnace is too small for most ceramic work, and the initial cost and cost of upkeep are high.

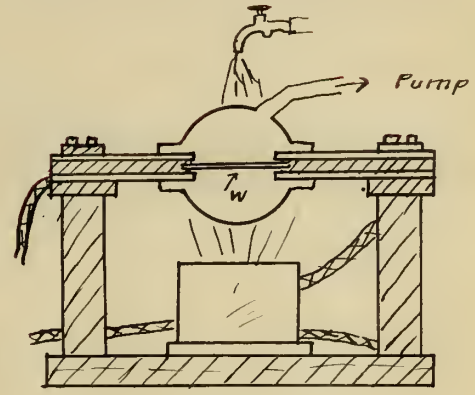


Fig. 4.

Another type which is being used is the molybdenum-resistance furnace. This can be used to a temperature of not over 2000°, the melting point of molybdenum being 2110°C. The disadvantage of this furnace is that the molybdenum readily oxidizes, and so the work must be carried on in a vacuum or in an inert atmosphere.

If some hgihly refractory substance could be found which did not volatilize appreciably or change form at high temperatures, and which would serve as a conductor of electricity with the proper resistance, it seems possible that it could be used as a substitute for the carbon in obtaining high temperatures. For this purpose metals are out of the question as their electrical resistance increases as the temperature is raised[4], and they melt at compara-

.....

[3] Fischer and Tiede in 'Chemical Abstracts' 1911 Vol. 5 pp. 3641

[4] A.A.Somerville in 'Physical Review', Vol. 31 pp. 261

tively low temperatures. The same is true of alloys. The resistance of iron pyrites decreases as the temperature is raised[5], but its dissociation temperature is too low to permit its use. Henderson and Weimer[6] found that porcelain gradually loses its resistance as the temperature increases, finally becoming a conductor. Stifler[7] found that magnesium oxide is an excellent insultor up to 800°C. after which it becomes quite conducting.

If a refractory substance could be found which would give sufficient conductivity at some temperature, it could be formed into a crucible which could be heated externally to this point. The source of heat could be removed at this stage and the temperature raised by passing a current thru the crucible itself. This principal is employed in the Nernst furnace. W. Nernst[8] has devised a furnace in which he uses a mixture of magnesia and calcium carbonate, alumina or silica, as magnesia alone has too high a resistivity. The resistor is a vertical tube surrounded by a non-heat-conductor, e.g., loose magnesia, lime or alumina, inclosed in a jacket. This tube is lined with magnesia, one or both sides of which lining may be covered with fine graphite to increase conductivity. Connection is made to the ends of the resistor by bodies of compressed ferric

.....

[5] E. Van Aubel in 'Science Extracts' Vol. 6 article 662.

[6] 'Transaction American Ceramic Society' Vol. 13 pp. 469
'Dialectric Strength of Porcelain Insulators.'

[7] 'Physical Review'. Vol. 32 pp. 429
'Tests on Certain Electric Insulators at High Temperatures.'

[8] 'Metallurgical and Chemical Engineering'
Vol. 8 pp. 606

oxide and metal clamps. The resistor is preheated to the temperature to pass a current by an internal carbon bar resistor, which is then withdrawn. The charge is then introduced, e.g., in a crucible pushed up from below. Preheating may be effected by a carbon or a platinum resistor; or by an initial resistor-layer of powdered carbon or silicon which burns away; or by burning coal gas or a mixture of a solid combustible and a nitrate.

The purpose of this work is to find some substance which in itself would fulfill the above requirements. The materials used were TiO_2, in the form of rutile, MgO, and Al_2O_3.

The effect of introducing H_2PtCl_6 into these oxides was also tried in order to determine its effect upon increase in conductivity.

-APPARATUS-

The apparatus used was:

Leeds and Northrup Decade Testing Set.

A reflection galvanometer.

Hoskins Electric Furnace.

Pyrometer and thermocouple.

2 standars dry cells.

The Leeds and Northrup instument, which involves the principal of the Wheatstone Bridge, recorded resistance up to 99,990,000 ohms. It was therefore impossible to determine higher resistances on account of this limitation. It was equipped with a galvanometer which was not sufficiently delicate for this work, and a reflection galvanometer was therefore substituted. The Hoskins furnace could be used only for temperatures up to 1000°, since the nichrome coil is liable to 'burn out' if the chamber temperature is carried higher

-METHOD-

The oxides were at first mixed with water and glue was used to bond them. But after the burn it was found that they did not possess enough bonding power of their own and crumbled. This was overcome by adding 15% ball clay to each body.

For the TiO_2, rutile passing a 60 mesh sieve was used; for the magnesia, MgO calcined to 1000°; and the alumina body was composed of

Alundum (100 mesh) --------	50%
$Al_2(OH)_6$ ----------	49%
$Al_2(OH)_6$ ppt. from $AlCl_3$ with ammonia -----	1%

These bodies were molded into cylinders by forcing them thru a $\frac{1}{2}$in. glass tube, and burned in a gas kiln to cone 6.

The apparatus was set up as shown in fig. 5, and contact was made by filing two grooves around each cylinder, 1 cm. apart, and winding the platinum electrodes snugly into these grooves.

For the second part of the experiment the bars were soaked in H_2PtCl_6 solution (10 cc. =.76 gms.) for twenty-four hours, dried in an electric oven at 110°, and cooled in a dessicator.

To prevent any error due to the uneven density of two or more bars of the same oxide or to the connections, one piece was used for all the tests on each particular oxide.

-RESULTS-

In all cases it was found that the electrical resistance of the oxides decreased as the temperature was raised. With rutile the greatest fall was apparent up to 700°, from which point the

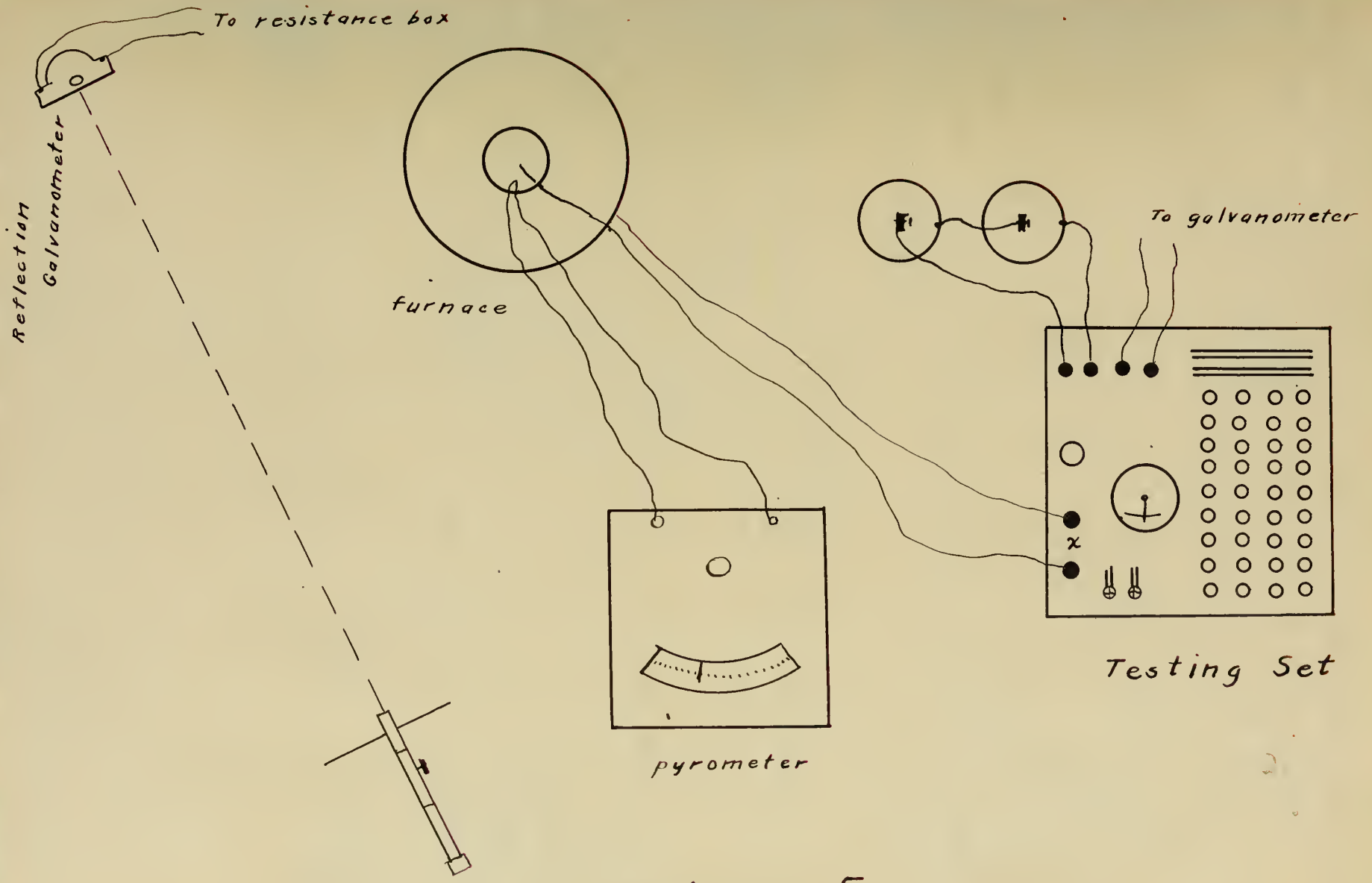

To resistance box
Reflection Galvanometer
furnace
To galvanometer
x
Testing Set
pyrometer

Fig. 5.

change was more gradual. With magnesia the curve fell off rapidly till 800° was reached. This was also true of the alumina.

The platinic chloride effected the pieces differently. With rutile there was no change whatever in the resistance. The effect on the magnesia and alumina was however very pronounced, the electrolyte increasing the conductivity greatly. This however was true for only the first trial in each case, for on reheating it was found that the electrolyte had lost its power of inducing conductivity, and the pieces had the same resistance as when the pure oxides were used.

-CONCLUSION-

Rutile, magnesia, and alumina, which are practically non-conductors at ordinary temperatures show a decrease in resistance as the temperature increases.

Altho this work has not been entirely successful in its purpose, the results seem promising enough that further work along this line would meet with success. The rate at which the resistance falls indicates that at some temperature not much above 1000° the bars would become conductors to a degree sufficient to generate heat.

The writer is unable to explain the action of H_2PtCl_6 in losing its power of inducing conductivity after the first test made on the pieces treated with this reagent.

RUTILE TiO_2 (Trial 1)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area
470	99,990,000	132,900,000
500	82,400,000	117,500,000
560	69,500,000	92,000,000
590	32,540,000	43,250,000
640	13,940,000	18,550,000
690	9,640,000	12,800,000
740	4,620,000	6,150,000
800	8,490,000	11,390,000
840	6,750,000	9,000,000
900	2,240,000	2,980,000
930	1,810,000	2,410,000
945	1,390,000	1,850,000

RUTILE TiO_2 (TRIAL 2)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
550	99,990,000	132,900,000
616	75,990,000	101,000,000
660	38,990,000	51,800,000
710	17,900,000	23,800,000
770	8,200,000	10,900,000
790	6,300,000	8,380,000
830	4,300,000	5,725,000
860	2,920,000	3,880,000
900	1,700,000	2,260,000
945	980,000	1,300,000
965	630,000	839,000
975	510,000	678,000
985	400,000	532,500
990	370,000	492,500

RUTILE TiO_2 (Trial 3)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
600	99,990,000	132,900,000
650	79,990,000	106,000,000
710	36,990,000	49,200,000
745	19,990,000	26,600,000
800	13,990,000	18,600,000
830	8,990,000	11,950,000
855	5,490,000	7,300,000
880	3,490,000	4,650,000
930	1,820,000	2,420,000
960	315,000	419,000
995	580,000	670,000
1000	450,000	598,000

RUTILE TiO_2 (Trial 4)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
625	99,990,000	132,900,000
690	21,990,000	29,200,000
735	7,990,000	10,600,000
785	3,250,000	4,325,000
810	1,990,000	2,660,000
870	1,050,000	1,398,000
920	590,000	785,000
960	360,000	479,000
980	272,000	362,000
1000	210,000	280,000

RUTILE with H_2PtCl_6

Length 1 cm.

Diameter 1.3 cm.

Temp. °C	Resistance, Ohms	Ohms per unit (cm.) length and area.
560	99,990,000	132,900,000
600	53,990,000	71,700,000
660	23,990,000	31,900,000
700	15,990,000	21,200,000
740	8,990,000	11,950,000
790	5,990,000	7,970,000
850	3,680,000	4,900,000
880	2,760,000	3,680,000

MAGNESIA MgO (Trial 1)

Length 1 cm.

Diameter 1.27 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
640	99,990,000	126,800,000
680	39,990,000	53,300,000
750	25,590,000	34,000,000
800	19,990,000	26,600,000
850	9,990,000	13,290,000
900	5,710,000	7,600,000
945	3,690,000	4,920,000
950	2,890,000	3,840,000
975	1,120,000	1,490,000

MAGNESIA MgO (Trial 2)

Length 1 cm.

Diameter 1.27 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
720	99,990,000	126,800,000
790	41,990,000	53,400,000
840	23,430,000	29,800,000
870	11,000,000	13,980,000
900	5,400,000	6,860,000
925	3,150,000	4,000,000
955	1,600,000	2,020,000
970	1,120,000	1,420,000
980	870,000	1,105,000
985	840,000	1,065,000
990	760,000	966,000

MAGNESIA with H_2PtCl_6 (Trial 1)

Length 1 cm.

Diameter 1,27 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
450	99,990,000	126,800,000
510	15,990,000	20,300,000
550	2,700,000	3,340,000
595	1,300,000	1,650,000
665	1,170,000	1,490,000
720	680,000	865,000
820	509,000	647,000
900	70,000	89,000
930	33,000	42,000
945	22,300	28,400
970	673,000	855,000
990	600,000	765,000

MAGNESIA with H_2PtCl_6 (Trial 2)

Length 1 cm.

Diameter 1.27 cm.

Temp. °C	Resistance, Ohms.	Ohms per unit (cm.) length and area.
650	99,990,000	126,800,000
680	59,990,000	76,400,000
755	27,990,000	35,600,000
790	17,990,000	22,900,000
860	5,900,000	7,500,000
930	1,640,000	2,090,000
960	990,000	1,260,000
990	630,000	802,000

ALUMINA Al_2O_3 (Trial 1)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
550	99,990,000	132,900,000
625	46,990,000	62,500,000
670	52,990,000	70,500,000
750	52,990,000	70,500,000
790	22,990,000	30,600,000
840	7,500,000	9,960,000
870	3,500,000	4,650,000
900	2,000,000	2,660,000
930	1,590,000	2,108,000
950	1,120,000	1,490,000
970	990,000	1,320,000
980	890,000	1,185,000

ALUMINA Al_2O_3 (Trial 2)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
710	99,990,000	132,900,000
750	23,990,900	31,900,000
830	3,990,000	5,300,000
860	2,590,000	3,440,000
930	1,030,000	1,370,000
970	845,000	1,140,000
985	737,000	980,000
990	727,000	968,000

ALUMINA Al_2O_3 (Trial 3)

Length 1 cm.

Diameter 1.3 cm.

Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
630	99,990,000	132,900,000
700	34,990,000	46,500,000
750	22,990,000	30,600,000
810	11,990,000	15,900,000
840	7,590,000	10,100,000
890	3,990,000	5,290,000
920	2,340,000	3,110,000
960	1,360,000	1,810,000
990	950,000	1,260,000
1000	860,000	1,160,000

ALUMINA with H_2PtCl_6

Length 1 cm.

Diameter 1.3 cm.

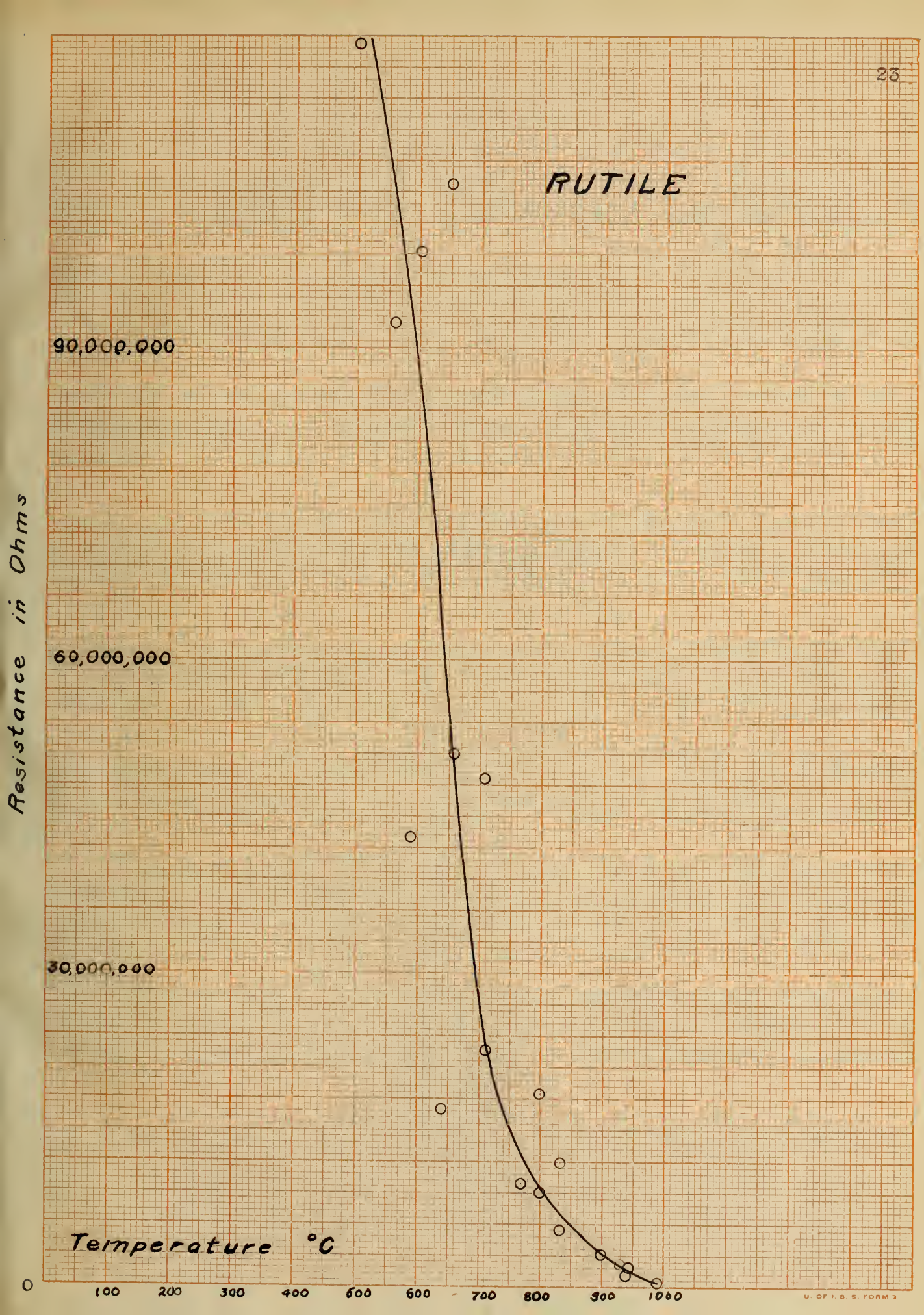
Temp. °C.	Resistance, Ohms.	Ohms per unit (cm.) length and area.
450	99,990,000	132,900,000
540	5,990,000	7,950,000
600	1,659,000	2,200,000
700	1,659,000	2,200,000
750	1,639,000	2,180,000
790	1,549,000	2,060,000
870	835,000	1,110,000
900	675,000	898,000
950	470,000	568,000
1020	247,000	279,000

ALUMINA with H_2PtCl_6 (Trial 2)

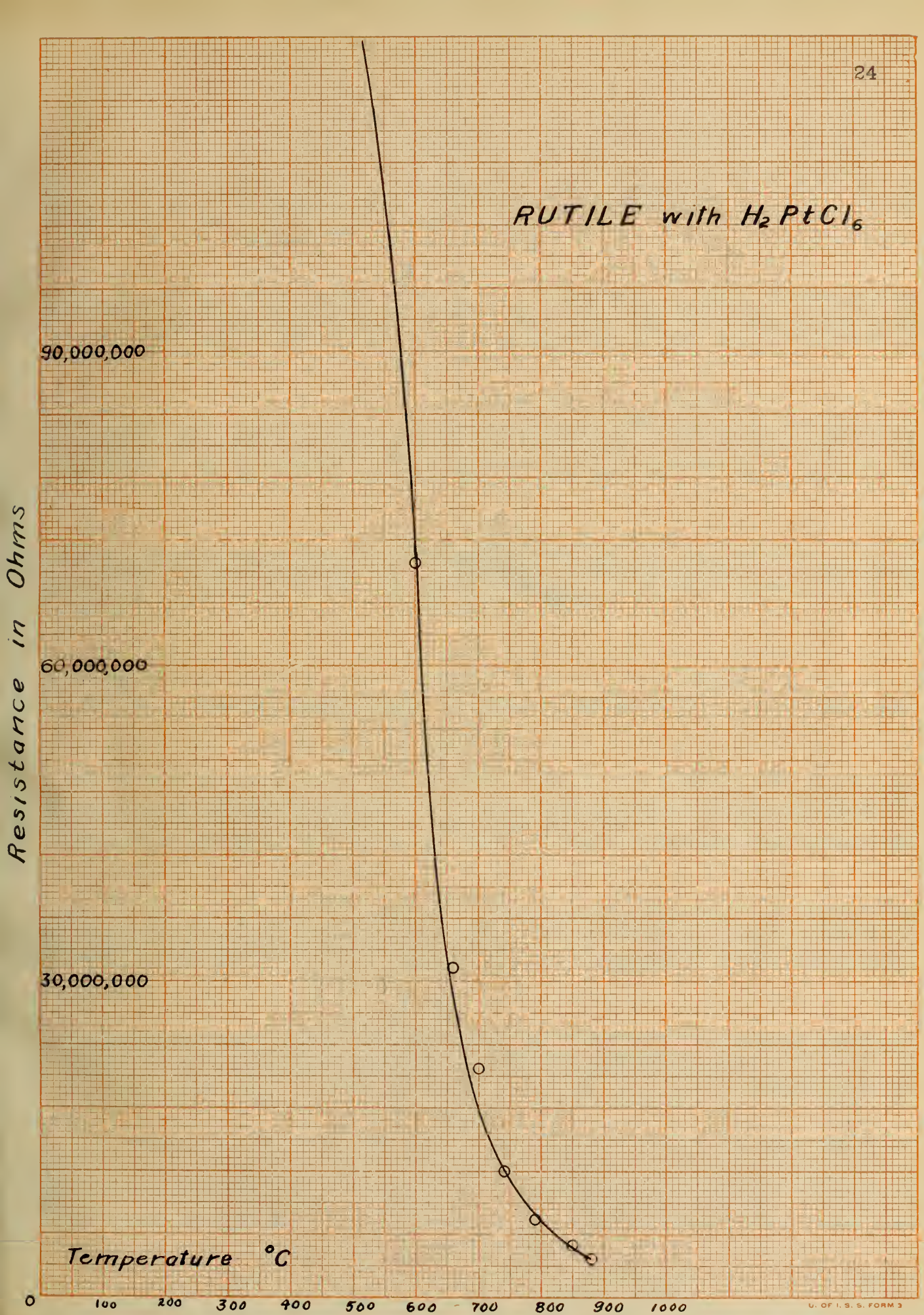
Length 1 cm.

Diameter 1.3 cm.

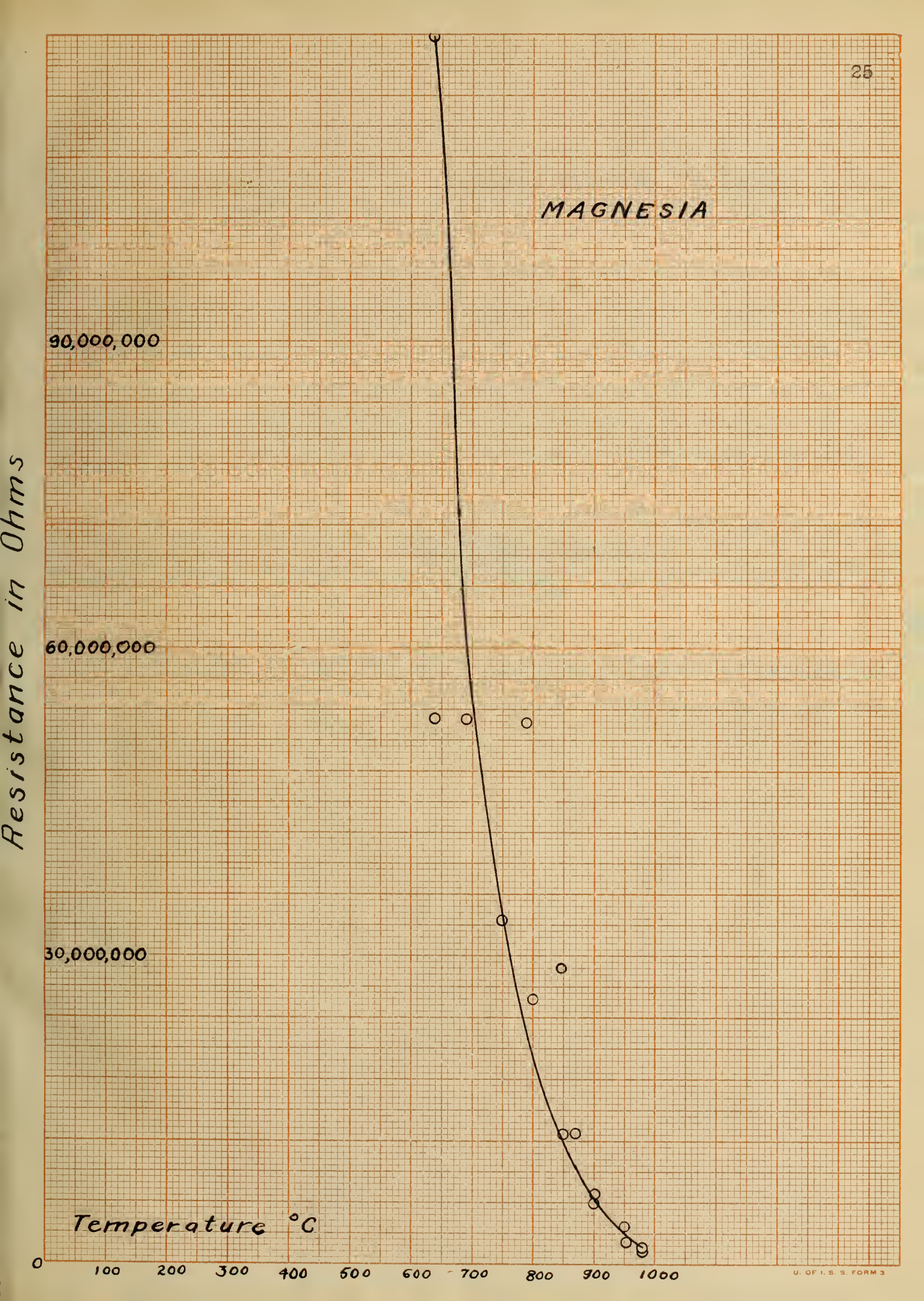
Temp. °C	Resistance, Ohms.	Ohms per unit (cm.) length and area.
580	99,990,000	132,900,000
670	46,990,000	62,500,000
769	13,990,000	18,600,000
835	4,190,000	5,580,000
890	1,780,000	2,370,000
930	920,000	1,225,000



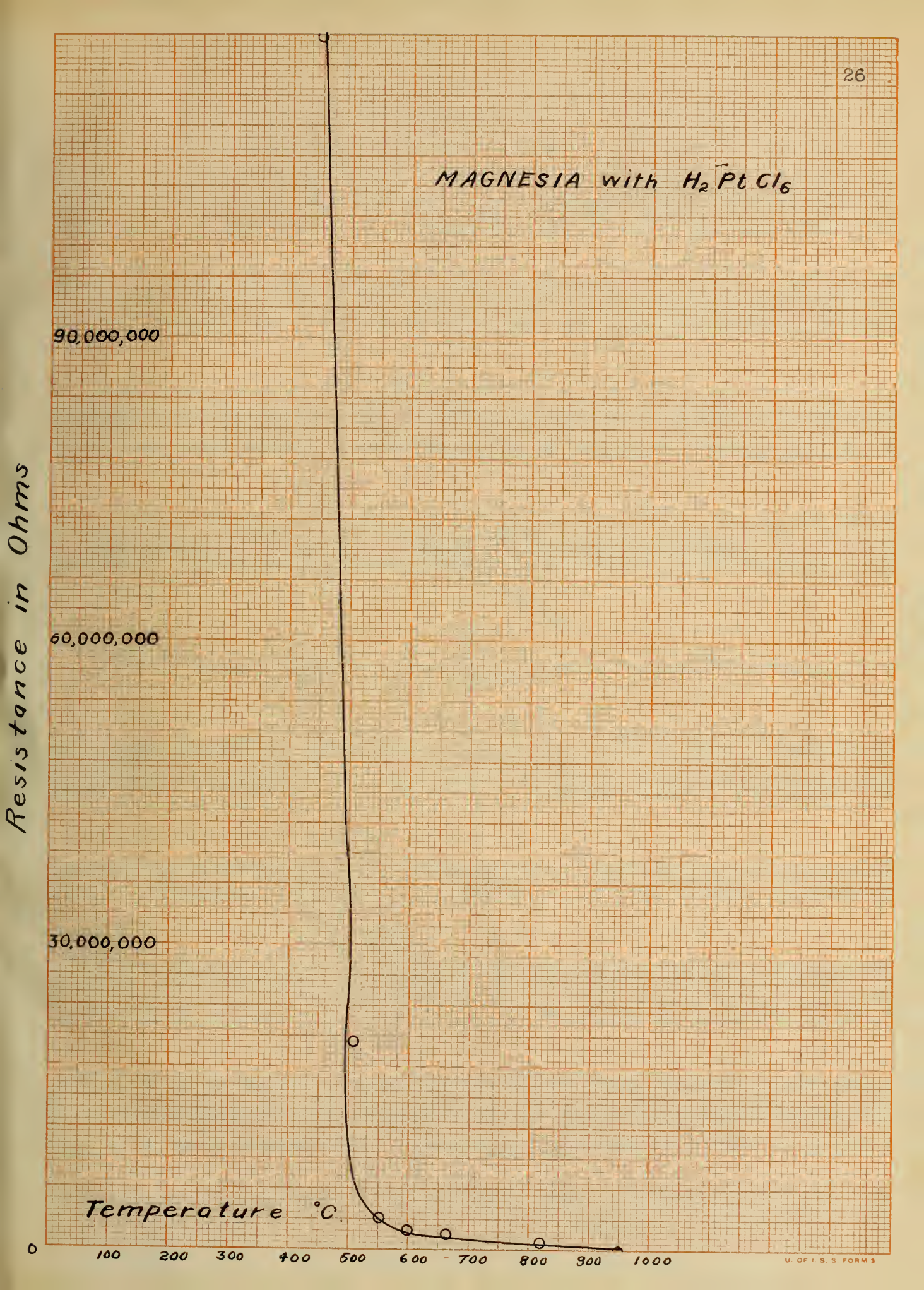
U. OF I. S. S. FORM 3



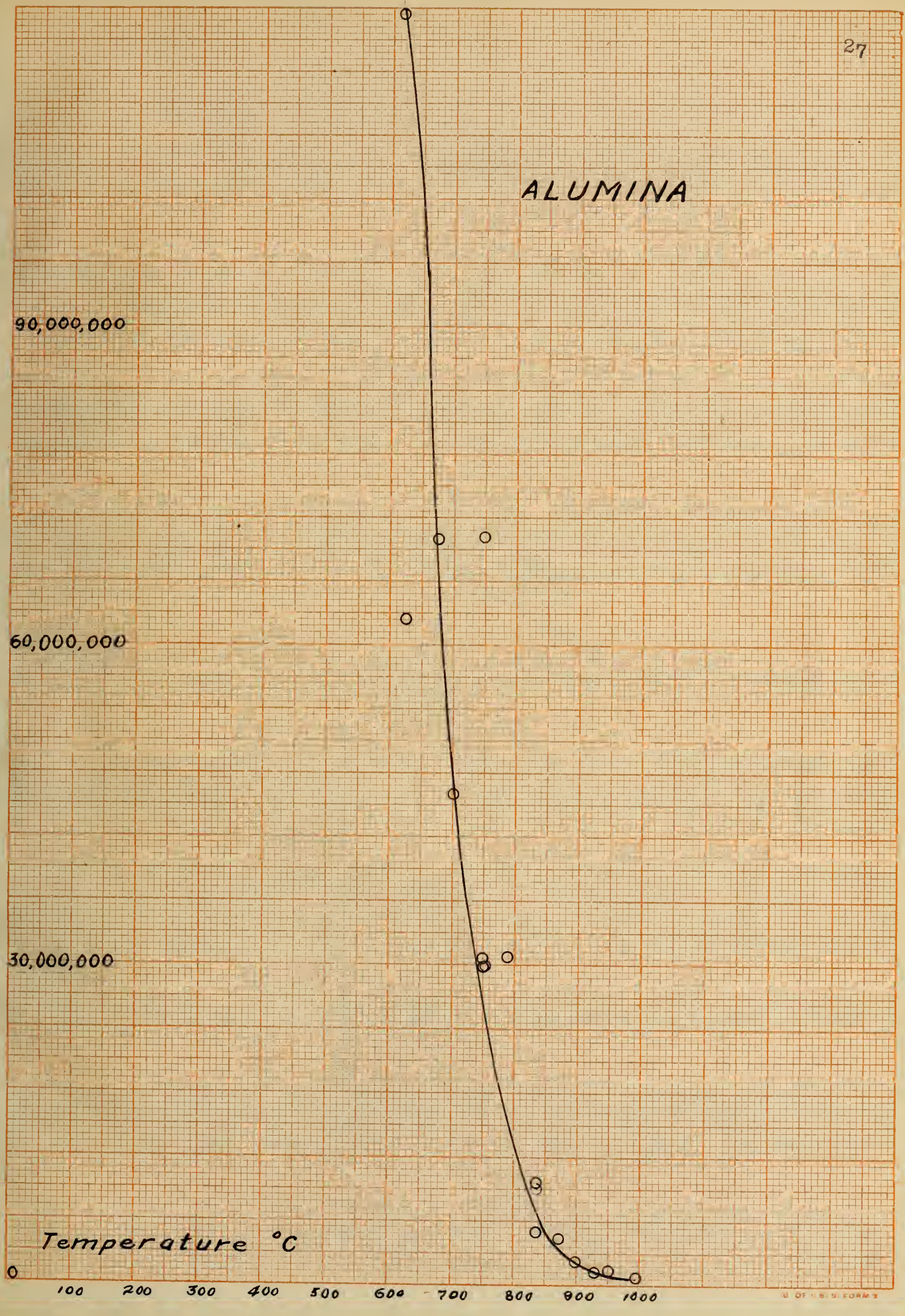
U. OF I. S. S. FORM 3

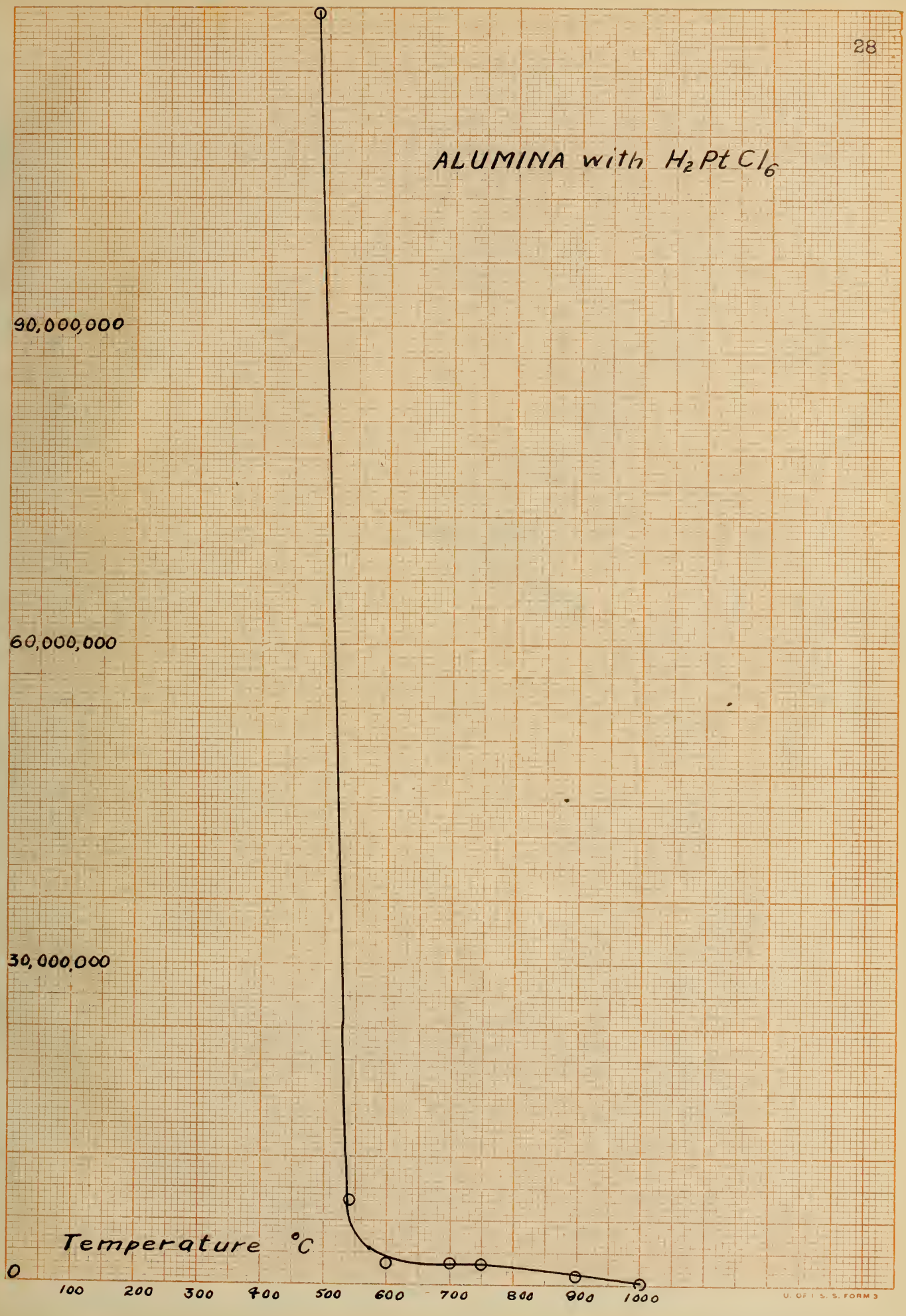


U. OF I. S. S. FORM 3



U. OF I. S. S. FORM 3


ALUMINA
90,000,000
60,000,000
30,000,000
Resistance in Ohms.
Temperature °C
100
200
300
400
500
600
700
800
900
1000



U. OF I. S. S. FORM 3

UNIVERSITY OF ILLINOIS-URBANA
3 0112 079827538